PART I

WATERSHED MODELING USING THE SOIL AND WATER ASSESSMENT TOOL (SWAT)

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WATERSHED CHARACTERISTICS

The Lake Aquilla Watershed is located in north central Texas **(Figure 1)**. It is predominantly located in Hill County, extending slightly into Johnson County. The reservoir controls runoff from 255 square miles, and deliberate impoundment began in April 1983. A search of USGS records indicated storage extremes: maximum contents, 119,000 acre-ft, December 23, 1991; minimum observed, 35,523 acre-ft, August 23, 1996.

The climate is sub-humid with an average annual precipitation of about 34 inches. The area is subject to high intensity, short duration thunderstorms during the spring and summer months. Typically summers are hot and winters are mild with intervals of freezing temperatures as cold fronts pass through the region.

The watershed is within portions of the East Cross Timbers, Grand Prairie, Texas Blackland Prairie, and Texas Claypan Major Land Resource Areas. Soils range from coarse-textured loamy sands in the Cross timbers to fine-textured montmorillonitic clays in the Blackland Prairie. Soil depths vary from shallow to deep. Upland topography ranges from nearly level to steeply sloping.

Typical crops grown in the area are corn, cotton, grain sorghum and wheat. About fifty percent of the cropland has effective terraces constructed on it. The remainder is either not terraced, or has worn down, ineffective terraces. Contour farming is not prevalent in the area, although most landowners with terraced cropland periodically re-build terraces to maintain the effective height.

METHODS

SWAT Model Description

The Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998) is the continuation of a long-term effort of nonpoint source pollution modeling by the USDA-Agricultural Research Service (ARS), including development of CREAMS (Knisel, 1980), SWRRB (Williams et al., 1985; Arnold et al., 1990), and ROTO (Arnold et al., 1995).

SWAT was developed to predict the impact of climate and management (e.g. vegetative changes, reservoir management, groundwater withdrawals, and water transfer) on water, sediment, and agricultural chemical yields in large un-gauged basins. To satisfy the objective, the model (a) is physically based; (b) uses readily available inputs; (c) is computationally efficient to operate on large basins in a reasonable time; and (d) is continuous time and capable of simulating long periods for computing the effects of management changes. SWAT allows a basin to be divided into hundreds or thousands of grid cells or sub-watersheds.

Geographic Information System (GIS)

In recent years, there has been considerable effort devoted to utilizing a GIS to extract inputs (e.g., soils, land use, and topography) for comprehensive simulation models and to spatially display model outputs. Much of the initial research was devoted to linking single-event, grid models with a raster-based GIS (Srinivasan and Engel, 1991; Rewerts and Engel, 1991). An interface was developed for SWAT (Srinivasan and Arnold, 1994) using the Graphical Resources Analysis Support System (GRASS) (U.S. Army, 1988). The input interface extracts model input data from map layers and associated relational databases for each subbasin. Soils, land use, weather, management, and topographic data are collected and written to appropriate model input files. The output interface allows the user to display output maps and graph output data by selecting a subbasin from a GIS map. This study was performed using GRASS GIS integrated with the SWAT model, both of which operate in the UNIX operating system.

More recent research has been devoted to linking the SWAT model with Arcview. The Arcview/SWAT interface operates in the PC Windows operating system.

GIS Data

Topography

The United States Geological Survey (USGS) database known as Digital Elevation Model (DEM) describes the surface of a watershed as a topographical database. The DEM database is a grid representation of elevation contour lines. Previously, the only DEM database that was available for all of Texas was the 1:250,000-scale data. This scale corresponded to a cell resolution of three arc seconds or about 100 meters. This database was usually adequate for computer models such as SWAT except in very flat watersheds. When using this database, manual digitizing or scanning to develop subbasin boundaries in a watershed was usually necessary.

Where the sub-basin size is less that a few hundred acres or in areas that are almost flat, the more detailed 1:24,000-scale DEM allows more accurate computer delineation of subbasins. The 1:24,000-scale corresponds to a cell resolution of one arc second or about 30 meters. This database recently became available for all of Texas. In the past computer time and storage requirements were obstacles when using high resolution 30 meter DEM's. Today, faster computers and new storage technology allow use of more detailed DEM's in modeling.

Subbasins in the Aquilla watershed **(Figure 1)** were delineated using the 30 meter, 1:24,000 scale DEM. The result was 136 subbasins with an average size of 1.9 square miles. The DEM is shown in **Figure 2**.

Soils

A soils database describes the surface and upper subsurface of a watershed. Models such as APEX and SWAT use information about each soil horizon. Parameters describing horizon thickness, depth, texture, water holding capacity, dispersion, etc. must be available to the model. These parameters are used to determine a water budget for the soil profile, daily runoff and erosion.

The Soil Survey Geographic (SSURGO) is the most detailed soils database available. This database is available as printed county soil surveys for over 90 percent of Texas counties. Electronic grid formats (30 meter resolution, 1:24,000 scale) for use in modeling is available in a few counties. The SSURGO database for Hill and Johnson counties was compiled in 1999 and is available in GIS format. The SSURGO databases for Hill and Johnson counties were

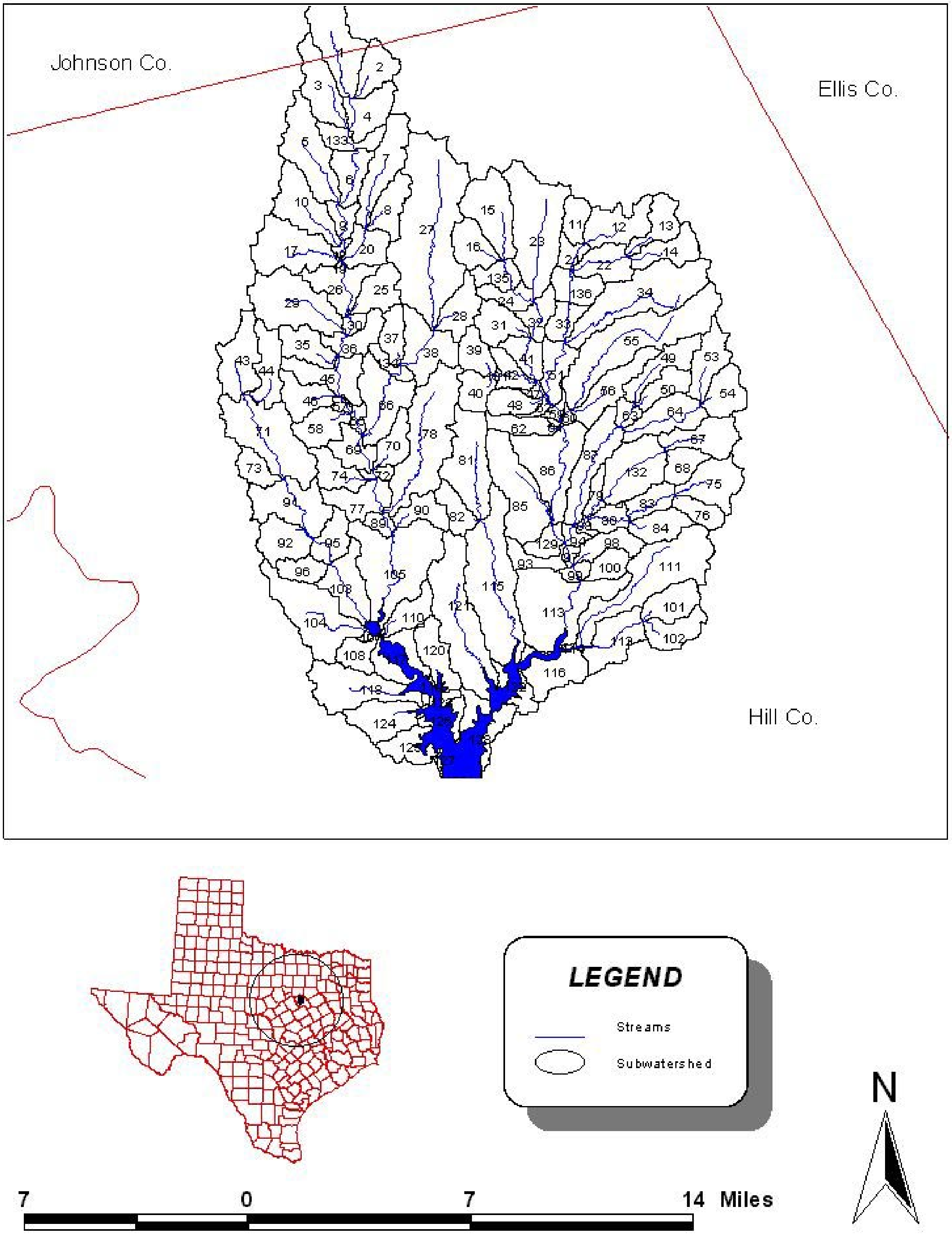

Figure 1. Subbasin map of Lake Aquilla Watershed.

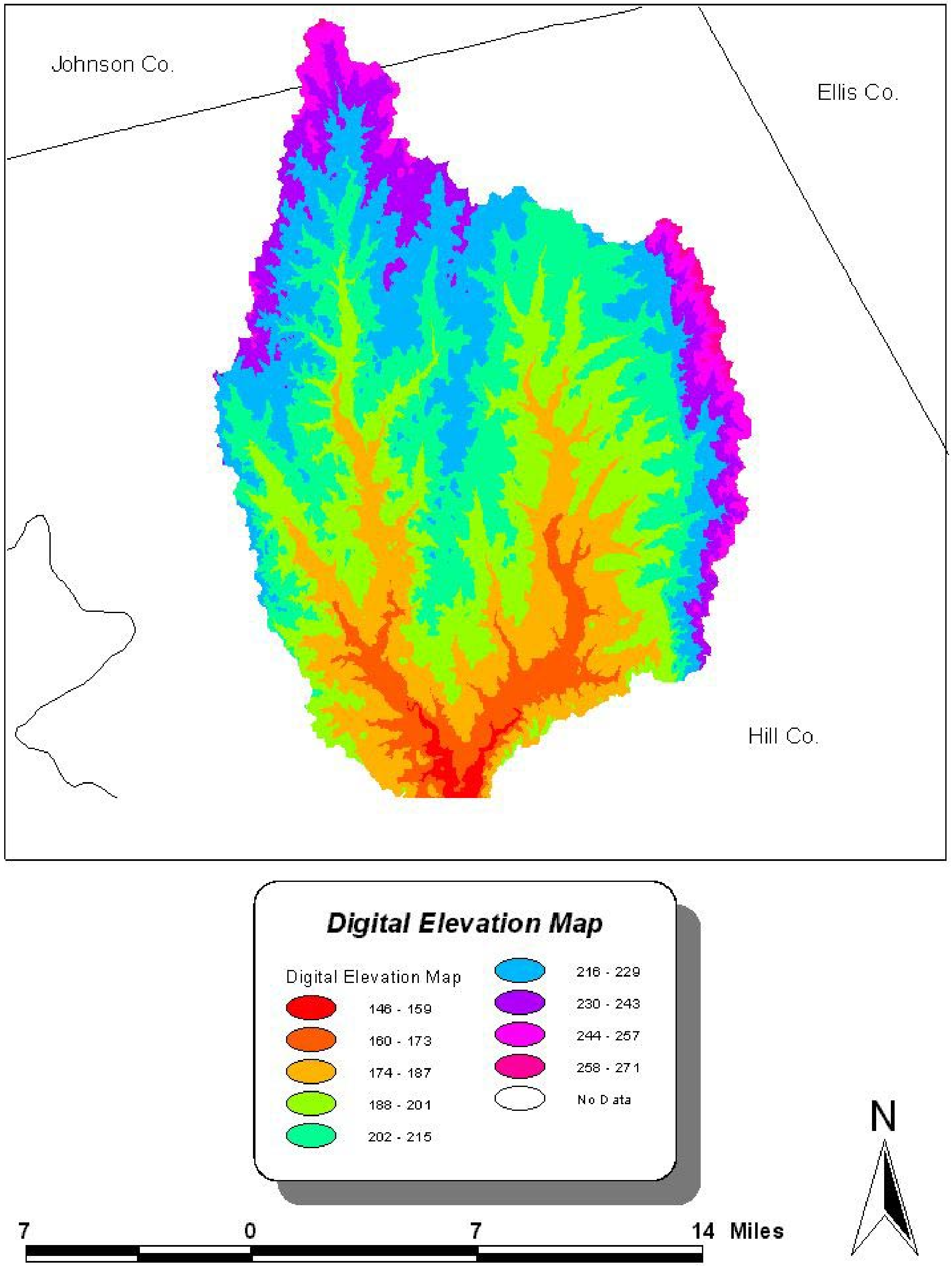

Figure 2. Digital Elevation Model (DEM) for Aquilla Watershed.

downloaded and patched together to create the soils database for the Aquilla watershed **(Figure 3)**. This database provides a much finer resolution of soils data than the previously used CBMS or STATSGO data.

The SWAT model uses the soil series name from each SSURGO polygon as the link between the soils GIS layer and the soils properties tabular database.

Land Use/Cover

Land use and cover affect surface erosion and water runoff in a watershed and is a necessary input of a watershed model. For this detailed study a new GIS land cover layer from the National Land Cover Data (NLCD) project was used. NLCD data is developed by the Multi Resource Land Characteristics Consortium (MRLC) from Landsat 5 Thematic Mapper (TM) satellite data archives and a host of ancillary sources. NLCD data has a resolution of 30 meters and will soon be available nationwide. It represents the first new land cover information since the 1970's. The NLCD land use map for the Aquilla watershed is shown in **Figure 4**. **Table 1** indicates the percentages of each land use in the watershed based on NLCD data. **Table 8** in the **Appendix** shows land use and cover by subbasin.

Table 1. Land use/cover in Lake Aquilla watershed.

Description	***Acres***	***Hectares***	***Cover (%)***
Cropland	47,791	19,341	29.33
Pastureland	76,890	31,117	47.18
Brushy Rangeland	22,203	8,985	13.62
Open Rangeland	4,046	1,637	2.48
Urban	4,735	1,916	2.90
Water	5,764	2,333	3.54
Wetland	149	60	0.09
Wheat Cropland	1,400	567	0.86
TOTAL	162,978	65,956	100.00

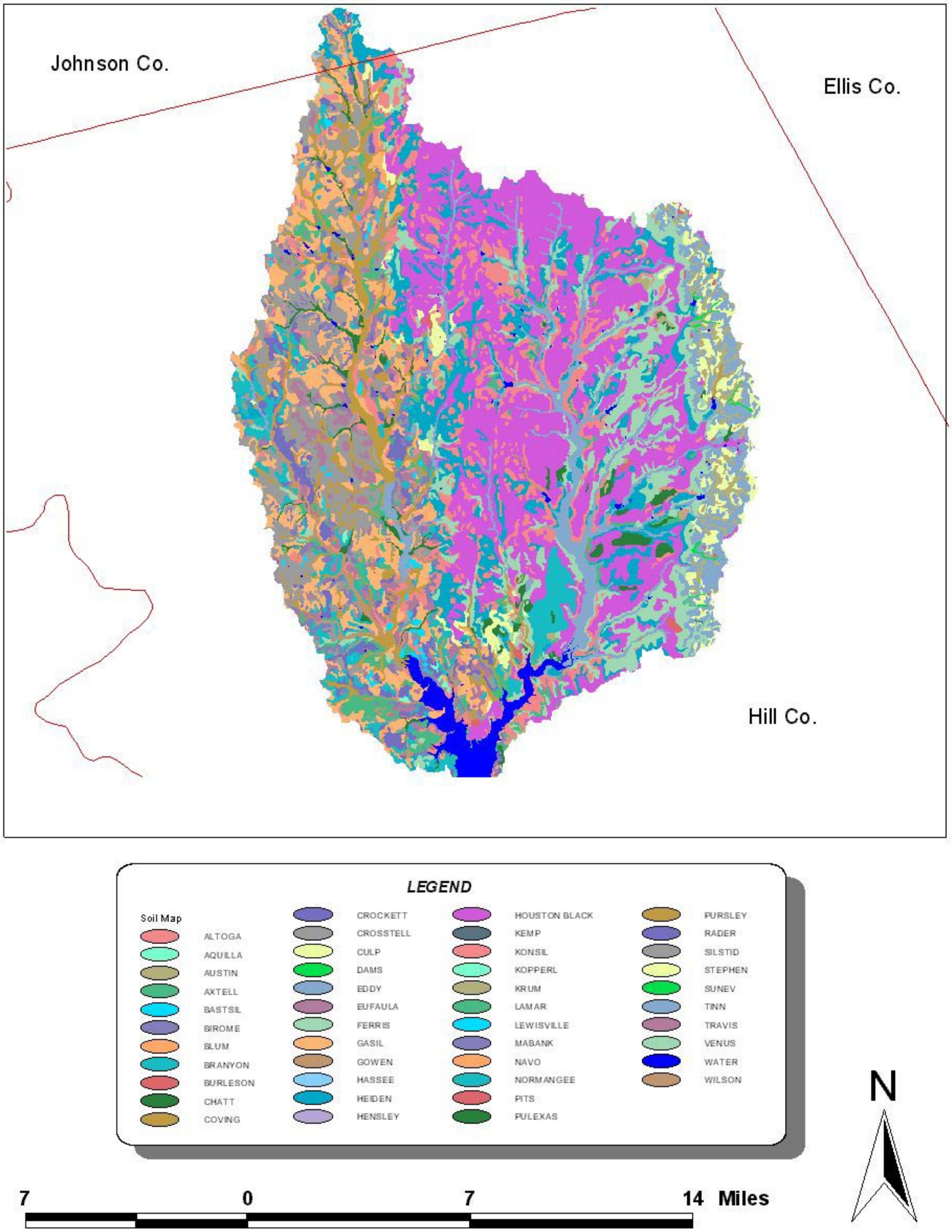

Figure 3. SSURGO soils map of Aquilla Watershed.

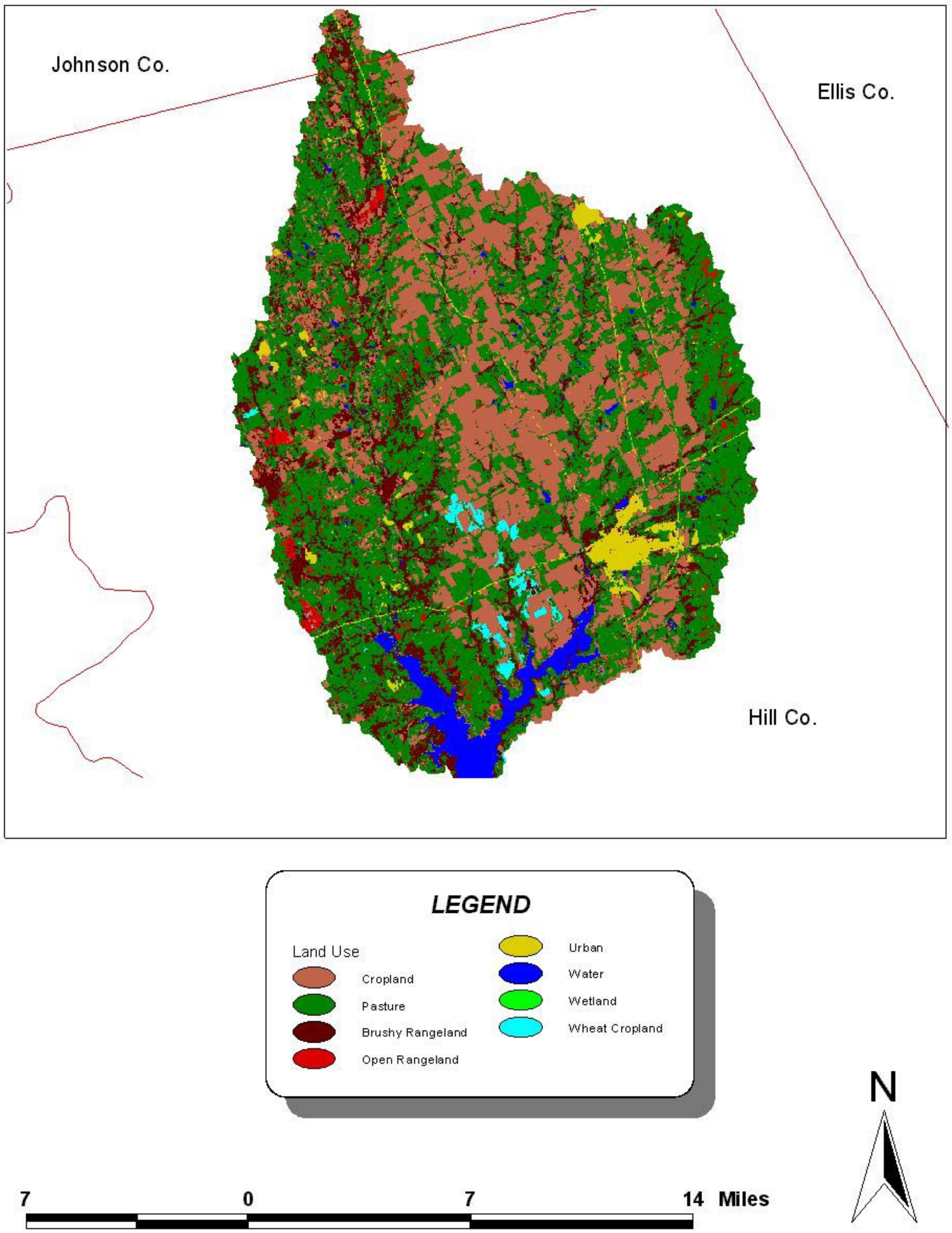

Figure 4. NLCD land use/cover map of Aquilla Watershed.

Climate

Daily precipitation totals and maximum and minimum temperatures were obtained for National Weather Service stations within and adjacent to the watersheds **(Figure 5)** for input to SWAT. The model uses rainfall and temperature data from the climate station nearest each subbasin. Climate stations outside the watershed, yet close enough to influence input data to the model, were included in the GIS database. The SWAT model generates precipitation and temperature data when station records contain missing data.

Table 2 lists precipitation stations located in or near the Aquilla watershed and the time periods for which data is available for each station. For the calibration model runs (1980 through 1992) and the long term simulations (1950 through 2000), data from stations at Cleburne, Hillsboro, and Whitney Dam were used. For the validation model run and short term sediment simulation (1996 through 2000), data from all six stations were used.

Table 2. Climate stations used in Aquilla watershed simulations.

Station Number	***Station Name***	***DATA TYPE***	***Start Date***	***End Date***
481800	Cleburne	Temp & Precip	1950	2000
484182	Hillsboro	Temp & Precip	1950	2000
489715	Whitney Dam	Temp & Precip	1950	2000
480297	Aquilla	Precip	1992	2000
484505	Itasca	Precip	1992	2000
484866	Kopperl	Precip	1992	2000

Dams and Reservoirs

Lake Aquilla is the only major reservoir within its drainage basin. Many other farm ponds and small reservoirs exist within the watershed. All dams included in state or federal inventories are contained in the GIS database developed for the simulations. The physical data for each reservoir were obtained from TNRCC and NRCS records and are contained in a relational database. This data is input to SWAT and enables simulation of the retarding effect on stream flow and sediment.

A list of all existing inventory-sized ponds and reservoirs within the Aquilla watershed is given in **Table 9** in the appendix. The location of existing and planned ponds and reservoirs is shown in **Figure 6**.

Geographic and Cartographic Features

ARC/INFO or GRASS can convert the Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing system) files into a GIS database. The resulting GIS layers consist of features such as highways, roads, city streets, streams, rivers and county lines. Names and classification of many of the features are available in the TIGER files. Statistical area boundaries are also included in the TIGER files. The TIGER lines are grouped into county files

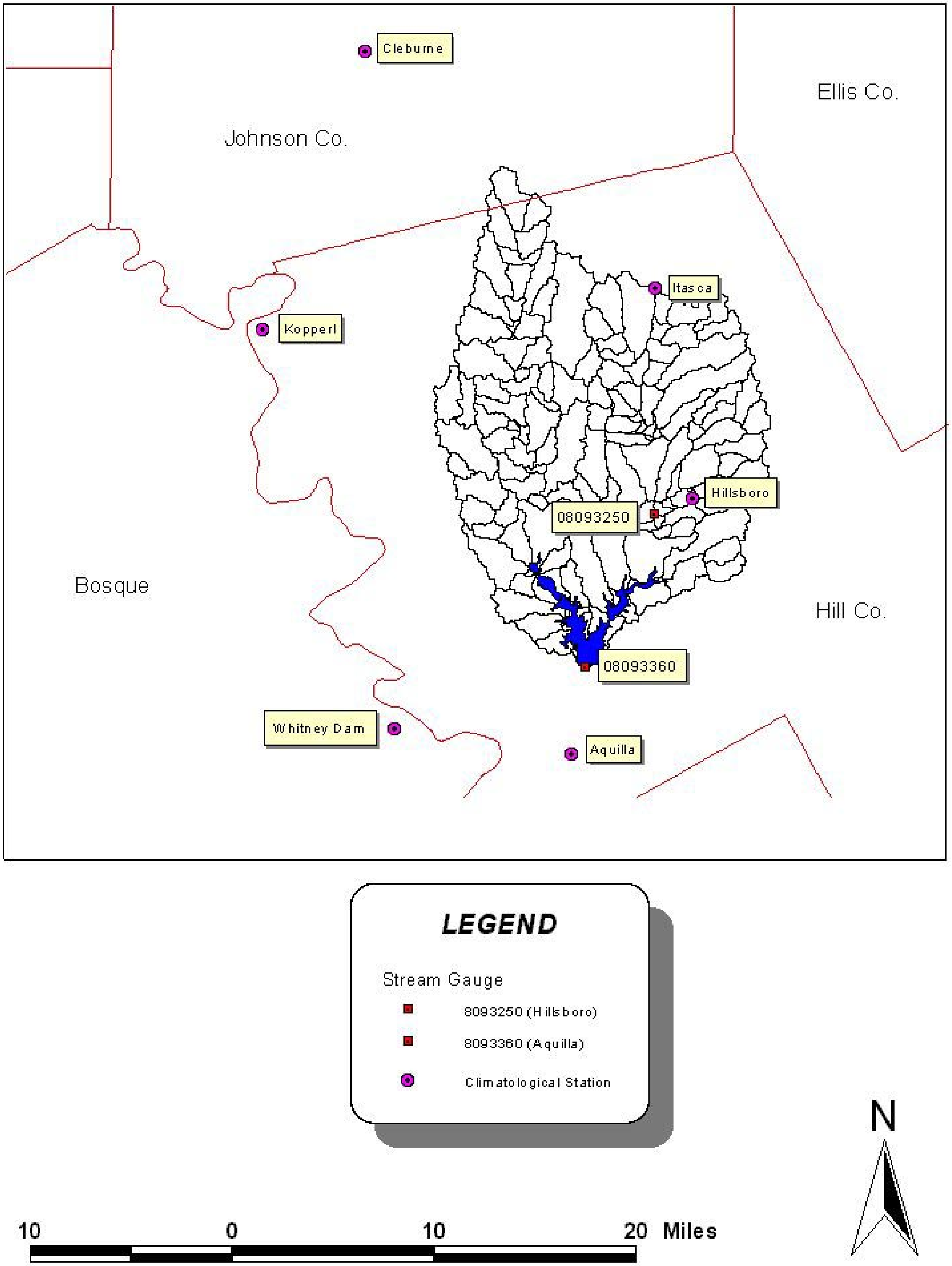

Figure 5. Climate stations and stream gauges for Aquilla watershed.

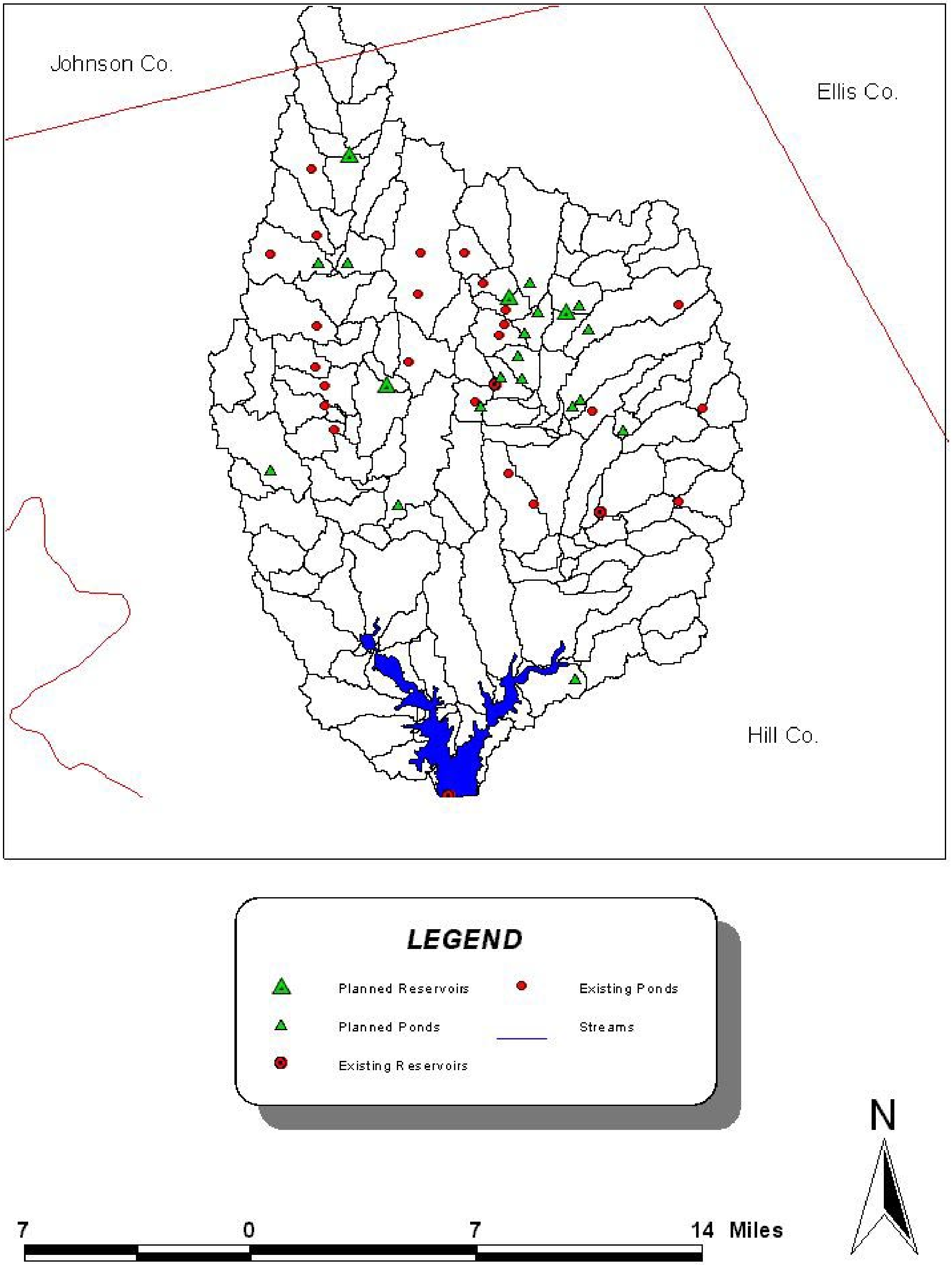

Figure 6. Ponds and reservoirs in Aquilla Watershed.

and are available by state for all of the United States. TIGER files are comparable to 1:100,000-scale topographic maps.

Another source of geographic and cartographic features is the 1:100,000-scale USGS DLG (Digital Line Graph) files. These files are available for almost all of Texas. Unlike the TIGER files, 1:100,000-scale DLG files do not contain political boundaries.

Particular layers are added to a graphical display in GRASS as needed for orientation or interpretation of the spatial data. TIGER 2000 cartographic features are shown in **Figure 7**.

Stream Flow Data

Historical stream flow data was obtained from the USGS records. Stream gauge stations located in the watershed are shown in **Figure 5**. Available period of record is shown in **Table 3**.

TABLE 3. Stream flow gauging stations in the Aquilla watershed.

Station Name	***Station Number***	***Start Date***	***End Date***
Hackberry Creek @ Hillsboro, TX	08093250	1980	1992
Aquilla Creek Above Aquilla, TX	08093360	1980	1991

Sediment Data

The Texas Water Development Board (TWDB) Hydrographic Survey Unit completed a hydrographic survey of Lake Aquilla in October 1995. The purpose of the survey was to determine the capacity of the lake at the normal pool elevation and to establish baseline information for future surveys. Originally, small reservoir surveys were conducted with a cable stretched across the reservoir along pre-determined range lines. A boat would manually measure the depth or use electronic depth sounders at selected intervals along the control cable. Larger water bodies prevented use of the cable but the same procedure would be used with surveying instruments employed to keep the path of the boat on the range line and to measure the incremental survey points. One advantage of this method was that surveys extended above the normal pool elevation, which allowed measurement of aerated sediment deposited during flood stages of the reservoir.

The new procedure utilizes Global Positioning System (GPS) technology to locate the horizontal position, and depth sounders to collect vertical measurements. All data is collected by an on-board computer, which later is used to calculate the lake volume. A disadvantage of this method is that aerated sediment is not measured, resulting in possibly inaccurate measurements in flood control reservoirs.

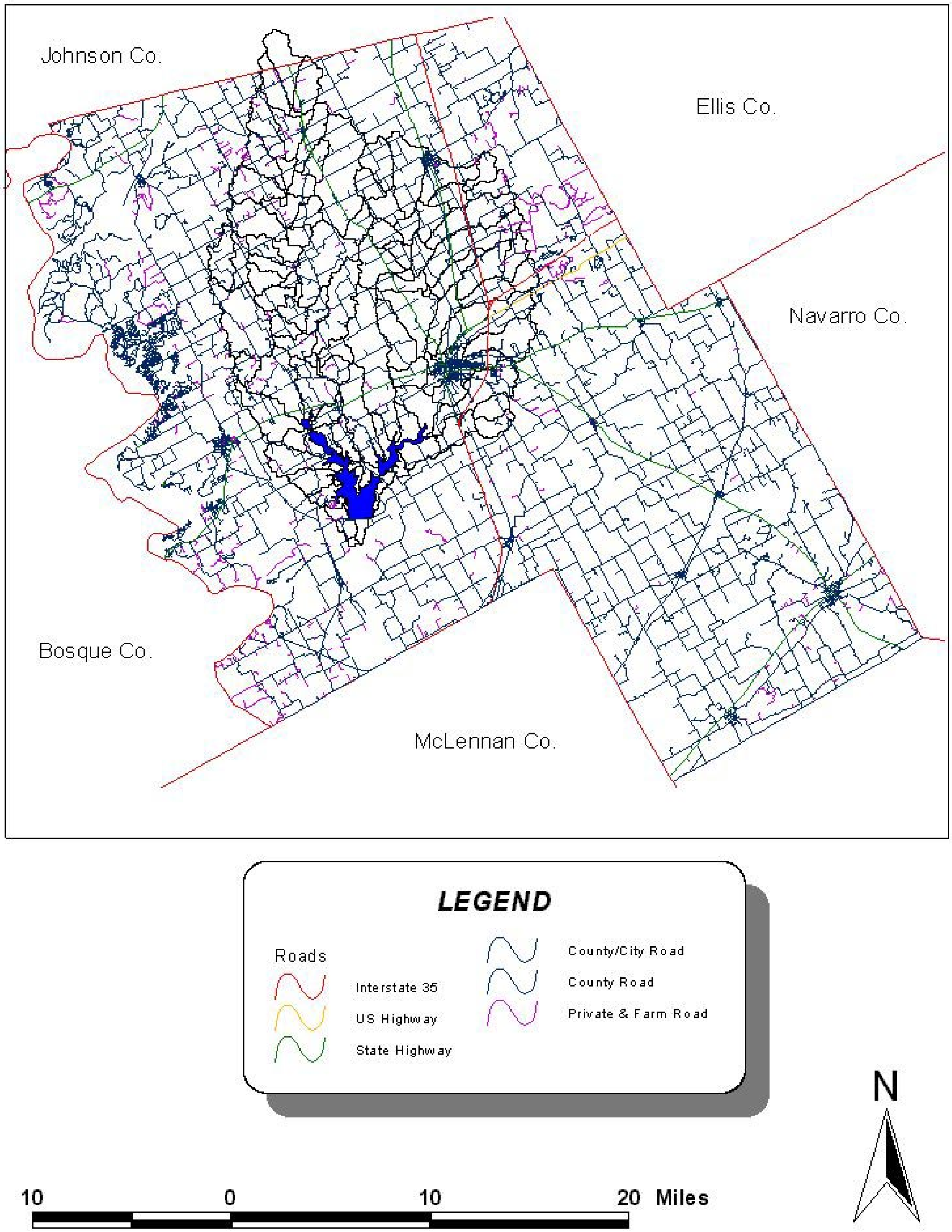

Figure 7. Cartographic features from TIGER 2000 data.

According to the TWDB survey, the storage capacity of the lake was reduced by 6,438 acre-feet between April 1983 (beginning of impoundment) and October 1995. Assuming the reduction in storage is due to sediment and that the unit weight of submerged sediment is 55 pounds per cubic foot, the amount of sediment deposited in the lake during this period was 7,010,982 metric tons.

The TWDB report "Volumetric Survey of Lake Aquilla" notes that it may be difficult to compare the results of the TWDB sediment survey with the original storage information because the methodology was very different. Reliable comparisons of lake volume through time will not occur until subsequent surveys are made using the new procedure in a similar manner.

Model Inputs

Subbasins were delineated using the 30-meter DEM and the Arcview interface for SWAT 99.2. The subbasin threshold area was set to 260 hectares. Site locations for reservoirs and stream gauges were used to define additional subbasin outlets, resulting in a total of 136 subbasins.

Required inputs for each subbasin (e.g. soils, land use/land cover, topography, and climate) were extracted and formatted using the SWAT/GRASS input interface. The input interface divided each subbasin into a maximum of 30 virtual subbasins or hydrologic response units (HRU). A single land use and soil were selected for each HRU. The number of HRU's within a subbasin was determined by: (1) creating an HRU for each land use that equaled or exceeded 5 percent of the area of a subbasin; and (2) creating an HRU for each soil type that equaled or exceeded 10 percent of any of the land uses selected in (1). The total number of HRU's (1,238) was dependent on the number of subbasins and the variability of the land use and soils within each subbasin. The properties for each of the selected land uses and soils were automatically extracted from model-supported databases.

A four-year rotation of grain sorghum-cotton-corn-grain sorghum was assumed for the cropland. A one-year rotation of winter wheat was assumed for the wheat cropland. Appropriate plant growth parameters for each crop were input for all model simulations.

Model Calibration

Flow

Measured flow at stream gauge 08093250 (Hillsboro) was used for calibration of SWAT. The calibration period (1980-1992) was based on the available period of record at this station. A base flow filter (Arnold et al., 1995) was used to determine the fraction of base flow and surface runoff. Adjustments were made to runoff curve number, soil evaporation compensation factor, shallow aquifer storage, shallow aquifer re-evaporation, and channel transmission loss until the simulated total flow and fraction of base flow were approximately equal to the measured total flow and base flow, respectively.

Gauge 08093360 was not used because it is downstream from Lake Aquilla, and flow is affected by the lake.

Sediment

The period 1983 through 1995 was used to calibrate SWAT for sediment loadings to Lake Aquilla. For this simulation, it was assumed that half the cropland was terraced with no contouring (based on personal communication with NRCS field staff at Hillsboro), and the other half was straight-row, up and down hill farming with no terraces. For these conditions, it was assumed the USLE conservation practice factor ("P") was 1.0 on all cropland.

In order to adjust sediment prediction, several factors are adjusted:

> Channel Erodibility Factor – Range is 0.0 to 1.0. A value of 0.0 indicates a non-erosive channel. A value of 1.0 indicates no resistance to erosion.
>
> Channel Cover Factor – Range is 0.0 to 1.0. A value of 0.0 indicates that the channel is completely protected from degradation by cover, and a value of 1.0 indicates there is no vegetative cover on the channel.
>
> Residue Decomposition Coefficient – Range is 0.01 to 0.09. The fraction of residue which will decompose in a day, assuming optimal moisture, temperature, C:N ratio and C:P ratio.
>
> Sediment Concentration Factor (SPCON) – Range is 0.0001 to 0.01. Linear parameter for calculating the maximum amount of sediment that can be re-entrained during channel sediment routing.
>
> Sediment Exponent Parameter (SPEXP) – Range is 1.0 to 1.5. Exponential factor for calculating sediment re-entrained in channel sediment routing.
>
> Peak Rate Function (PRF) – Range is 0.5 to 2.0. Peak rate adjustment for sediment routing in the channel. Sediment routing is a function of peak flow rate and mean daily flow. Because SWAT cannot directly calculate the sub-daily hydrograph, this variable was incorporated to allow adjustment for the effect of the peak flow rate on sediment routing. This variable impacts channel degradation.

It was assumed the stream channel erodibility factor was 0.12, the channel cover factor was 1.0 (no vegetative cover), and the residue decomposition factor (RSDCO) was 0.05. The sediment parameters SPC, SPE, and PRF were then adjusted to give the best results for predicted sediment. The final values were SPC=0.050, SPE=1.000, and PRF=1.000.

RESULTS

Flow Calibration

Flow calibration results for the Hillsboro stream gauge (08093250) are shown in **Figure 8**. Predicted total flow compares reasonably well with measured flow. The monthly time series shown reveals that SWAT under-predicts flow in some periods and over-predicts in others. This is most likely due to missing precipitation data in the station records or rainfall variability that is not reflected in the measured data. Rainfall variability is caused by localized thunderstorms occurring over climate stations or between stations, and spatial distribution of storms not accurately represented in the precipitation data input to SWAT.

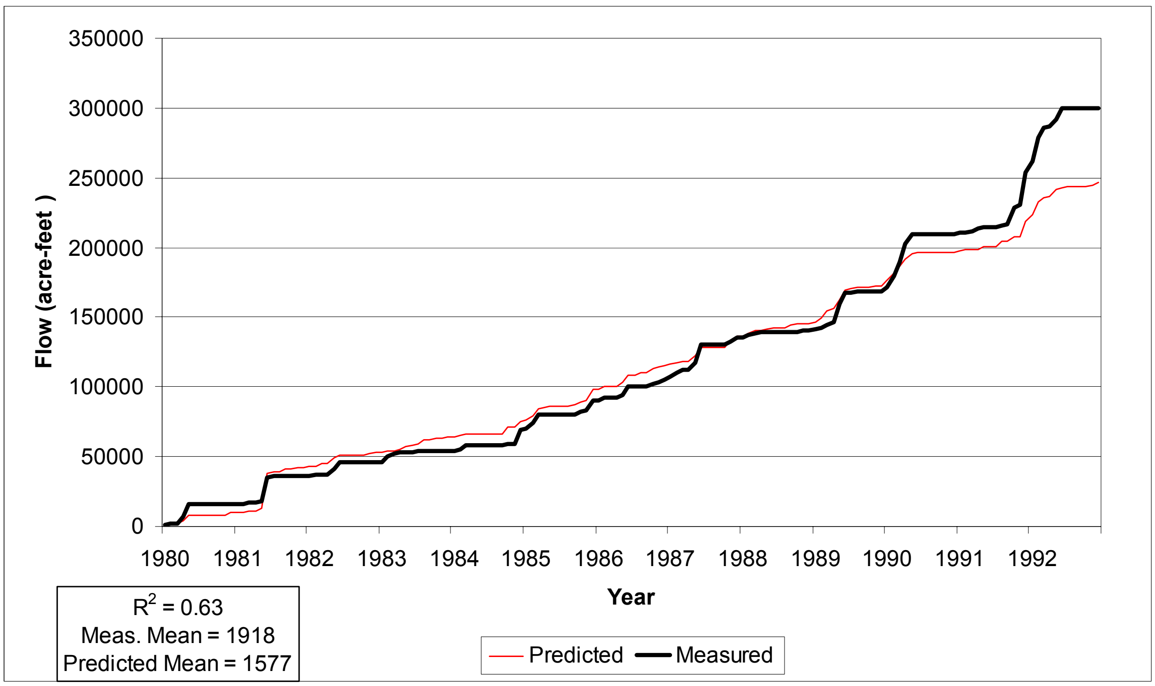

Figure 8. Cumulative monthly measured and predicted stream flow at gauge 08093250 (Hackberry Creek near Hillsboro), 1980 through 1992. Monthly statistics are shown in box.

Sediment Calibration

The simulated sediment load for Lake Aquilla for the 1983-1995 period was 7,014,634 metric tons, which was very close to the measured sediment of 7,010,982 metric tons. A monthly time series of cumulative simulated sediment is shown in **Figure 9**. Although the results of the calibration are satisfactory, it should be noted that the weight of measured sediment is based on assumed sediment density.

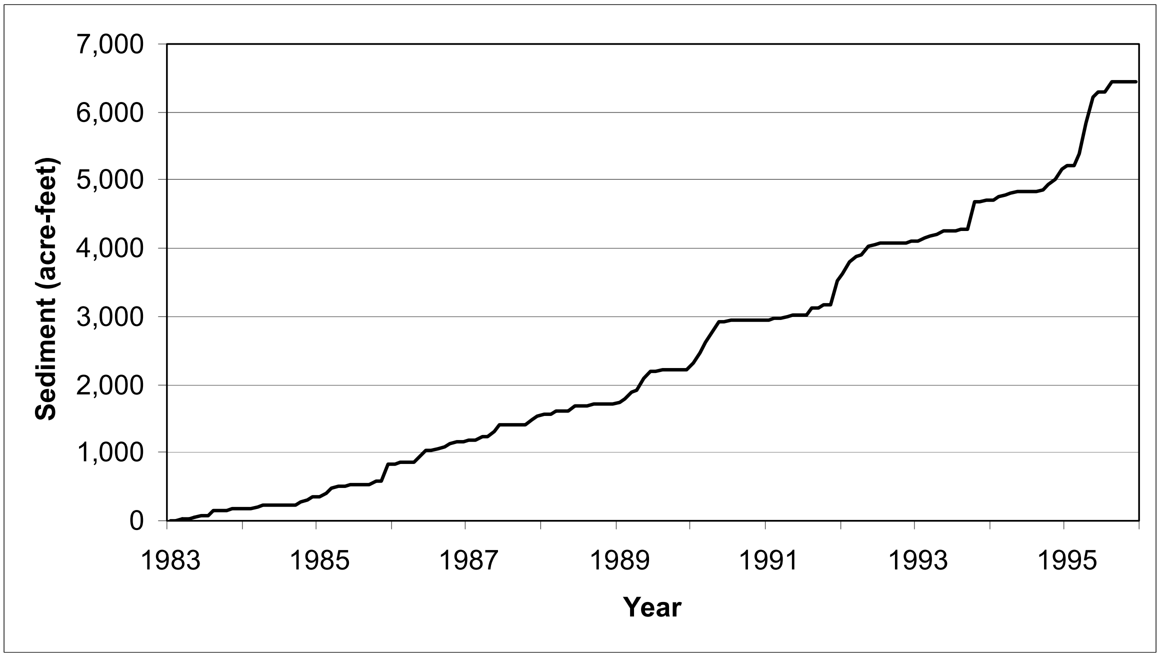

Figure 9. Cumulative monthly predicted sediment into Lake Aquilla, 1983 through 1995.

BMP Simulations

Simulation of land treatment scenarios included the following BMP's:

- No-till farming
- Terrace construction with contour cultivation
- Construction of new sediment-retention reservoirs

Scenarios were set up to examine how Best Management Practices (BMP's) would affect sediment loadings to Lake Aquilla. Each scenario was simulated for the 1950 – 2000 period.

<u>Scenario 1 – Current Conditions</u>

After calibration was completed for flow and sediment, this simulation was re-run for the 51-year period. This simulation represented the current conditions. Existing ponds and reservoirs were included, as well as the predominant crops grown in the area and typical management techniques including tillage, fertilization, and conservation practices. Fifty percent of the cropland was assumed terraced with no contouring.

<u>Scenario 2 – No-till Tillage</u>

Conservation tillage is defined as having at least 30 percent ground cover after planting and is also known as crop residue management. These practices will improve soil quality, water quality, air quality and on-farm productivity while reducing expenses. No-till, one type of conservation tillage, is especially effective at reducing soil erosion and conserving soil moisture for drier periods. Soil tilth and infiltration are improved through increased soil organic matter. This scenario assumed no-till management on all cropland in the Lake Aquilla watershed.

Scenario 3 – Terraces with Contour Farming

Most existing terrace systems in the watershed were built many years ago when farmers used much smaller equipment. As a result, these obsolete terraces cannot accommodate new wider implements and are no longer effective. Modern parallel terraces are designed to accommodate today's larger equipment and cropping systems. Terraces reduce soil erosion by reducing the slope length and allowing farm operations on the contour. This scenario assumed 100 percent of cropland was terraced and contoured with conventional tillage.

Scenario 4 – Terraces with Contour Farming and No-till Tillage

This simulation combined the best management practices of scenarios two and three.

Scenario 5 – Planned Ponds and Reservoirs

This scenario models the addition of 17 ponds and 4 reservoirs (floodwater retarding structures or sediment control structures). These additional structures **(Figure 6),** which were included in the USDA – NRCS Aquilla-Hackberry Creek Watershed Work Plan, have either not been constructed yet or were deleted from the project. This scenario also assumed conventional tillage with terracing on 50 percent of the cropland (no contouring).

Scenario 6 – Install all BMP Practices Included in Previous Scenarios.

The final alternative for the watershed assumed a combination of no-till tillage, terraces with contour farming, and installation of 21 new ponds and reservoirs.

Table 4 outlines the details of each scenario modeled for the Aquilla watershed. **Table 5** presents the predicted cumulative sediment loads into the reservoir, and **Table 6** gives relative sediment reductions for each scenario. **Figure 10** depicts the predicted average annual sediment load to the lake for each scenario.

The results of the current study indicated that cropland BMP's may reduce sediment by 21 percent as compared to the predicted reduction of 3 percent in the previous study (1998). One possible explanation for this difference is that more detailed GIS data used in the current study provided greater modeling accuracy. In addition, the sheet and rill erosion subroutines in SWAT (land phase of the model) have been improved since the original study.

Assuming installation of additional ponds or reservoirs resulted in a sediment reduction of 21 percent in the current study, as compared to 33 percent in the previous study. Ponds and reservoirs have a greater effect on stream channel erosion (water phase of the model). The proportion of total sediment coming from stream channel erosion is lower in the current study because of improved land phase erosion prediction. This caused the effects of ponds and reservoirs on sediment reduction to be less in the current study.

Assuming application of all BMP's resulted in a sediment reduction of 37 percent, which is similar to the 33 percent reduction predicted in the previous study. Average annual and total sediment deposition in Lake Aquilla for selected scenarios and time periods for both the previous study and the current study are shown in **Table 7** for comparison.

Table 4. Configuration of modeling scenarios.

Scenario Number	*Existing Ponds*	*Planned Ponds*	*Conservation Treatment*	*Tillage*	*P Factor*
1	√		50 % Terraced (no contouring)	Conventional	1.0
2	√		50 % Terraced (no contouring)	No-Till	1.0
3	√		100 % Contoured & Terraced	Conventional	0.5
4	√		100 % Contoured & Terraced	No-Till	0.5
5	√	√	50 % Terraced (no contouring)	Conventional	1.0
6	√	√	100 % Contoured & Terraced	No-Till	0.5

Table 5. Predicted total sediment for each scenario.

		Simulation Period	*1983-1995*	*1950-2000*
		Number of Years	*13*	*51*
	Scenario	*Units*	*(calibration)*	
1	Ex Ponds, Conv Till, P=1	metric tons	7,014,634	26,036,964
		acre-feet *	6,455	23,959
2	Ex Ponds, No-Till, P=1	metric tons	NA	24,716,536
		acre-feet *	NA	22,744
3	Ex Ponds, Conv Till, Terrace & Contour, P=0.5	metric tons	NA	21,165,192
		acre-feet *	NA	19,476
4	Ex Ponds, No-Till, Terrace & Contour, P=0.5	metric tons	NA	20,572,636
		acre-feet *	NA	18,931
5	Ex & Plan Ponds, Conv Till, P=1	metric tons	NA	20,557,710
		acre-feet *	NA	18,917
6	Ex & Plan Ponds, No-Till, Terrace & Contour, P=0.5	metric tons	NA	16,357,909
		acre-feet *	NA	15,052

- *Volume in acre-feet assuming a sediment density of 55 pounds per cubic foot.*

Table 6. Relative sediment reductions for each scenario.

Compared Scenarios	*Relative Sediment Reductions*
1 vs. 2	Assuming no-till cultivation on cropland reduces sediment by 5%
1 vs. 3	Assuming terraces with contour farming on all cropland reduces sediment by 19%
1 vs. 4	Assuming no-till with terraces & contour farming reduces sediment by 21%
1 vs. 5	Assuming installation of "planned" ponds reduces sediment by 21%
1 vs. 6	Assuming application of all BMP's in scenarios 4 & 5 reduces sediment by 37%

Table 7. Comparison of simulated sediment deposition in Lake Aquilla (current study vs. previous study).

Scenario				*Sediment Deposition (Acre – Feet) **		
Description	***Old Num.***	***New Num.***	***Units***	***1950-1995 (previous)***	***1950-1995 (current)***	***1950-2000 (current)***
Existing Condition (Conv. Tillage, 50% terraced)	1	1	Ave. Annual	438	456	470
			Total	20,128	20,963	23,959
No-Till, Contoured and Terraced	5	4	Ave. Annual	426	358	371
			Total	19,531	16,481	18,931
Construct New Ponds	4	5	Ave. Annual	295	360	371
			Total	13,555	16,539	18,917
Apply All BMP's (combination of 4 & 5)	6	6	Ave. Annual	284	285	295
			Total	13,072	13,092	15,052

** Volume in acre-feet assuming a sediment density of 55 pounds per cubic foot.*

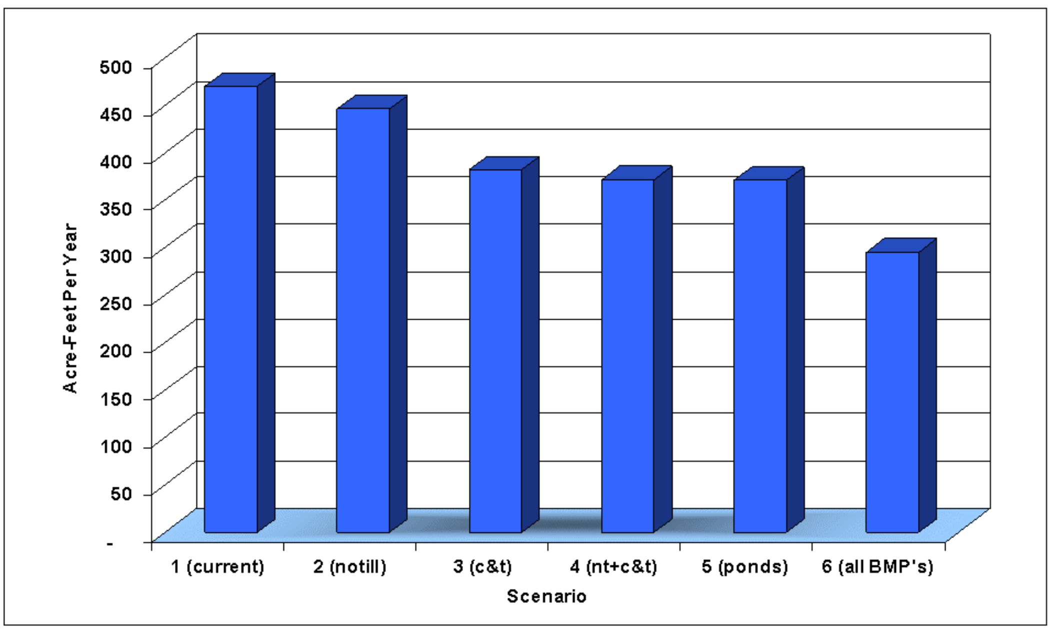

Figure 10. Predicted average annual sediment load to Lake Aquilla, 1950 through 2000.

Figure 11 depicts the average annual watershed sediment load on a per-acre basis for each scenario, showing the fractions of the sediment attributed to land phase (sheet and rill) and water phase (stream channel) erosion. The graph shows that as land phase erosion was reduced by application of BMP's, water phase erosion increased, although total erosion was reduced. The graph also shows that ponds and reservoirs have a greater impact on water phase erosion.

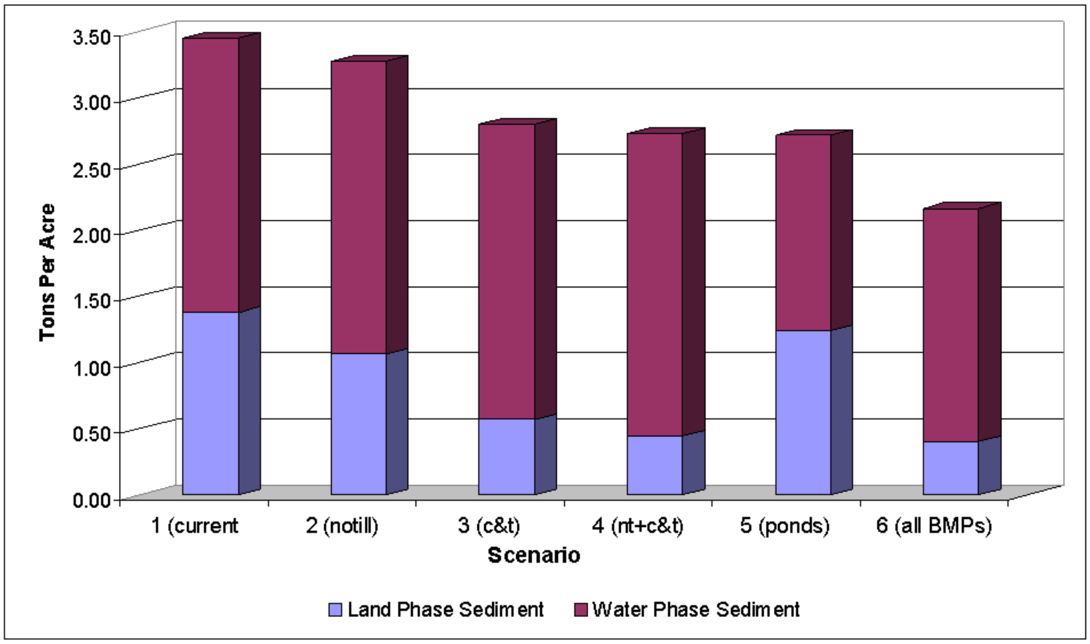

Figure 11. Predicted average annual sediment load to Lake Aquilla per unit area, 1950 through 2000.

Figures 12 through 15 are color graphs of the Aquilla watershed subbasins which depict modeling results. **Figure 12** shows the fraction of cropland in each subbasin. **Figure 13** gives sediment yield (land phase erosion) for the current condition, and **Figure 14** shows sediment yield assuming application of all BMP's. Note that subbasins with higher sediment yields also have greater cropland fractions.

Channel erosion (water phase) per unit subbasin area for each subbasin is shown in **Figure 15.** Small subbasins with large upstream drainage areas flowing through them usually show greater unit-area channel erosion.

Table 10 in the appendix gives water and sediment yield by subbasin for each scenario. Channel erosion per unit area for the current condition is given by subbasin in **Table 11** of the appendix.

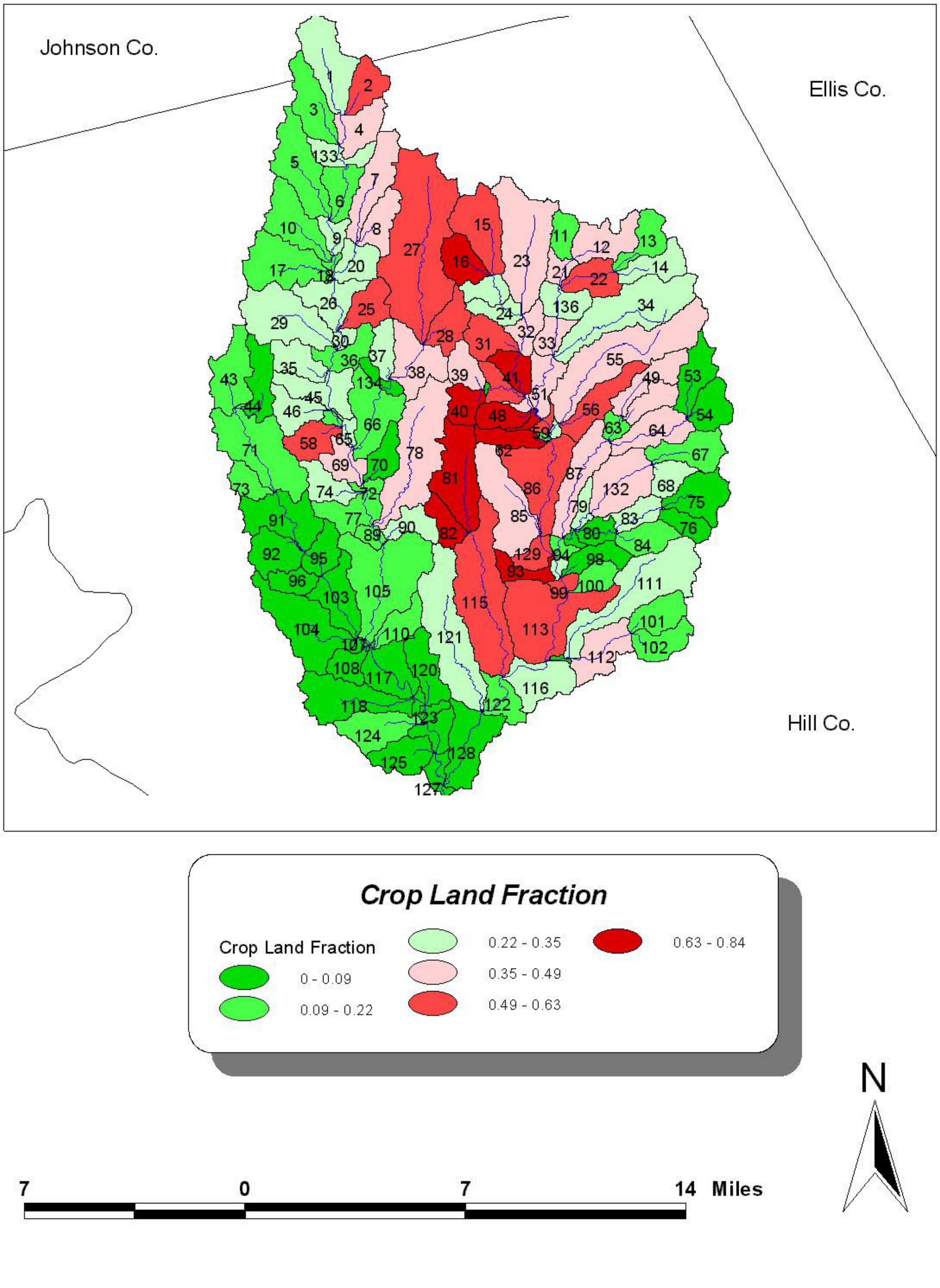

Figure 12. Fraction of subbasin area that is cropland in Aquilla watershed.

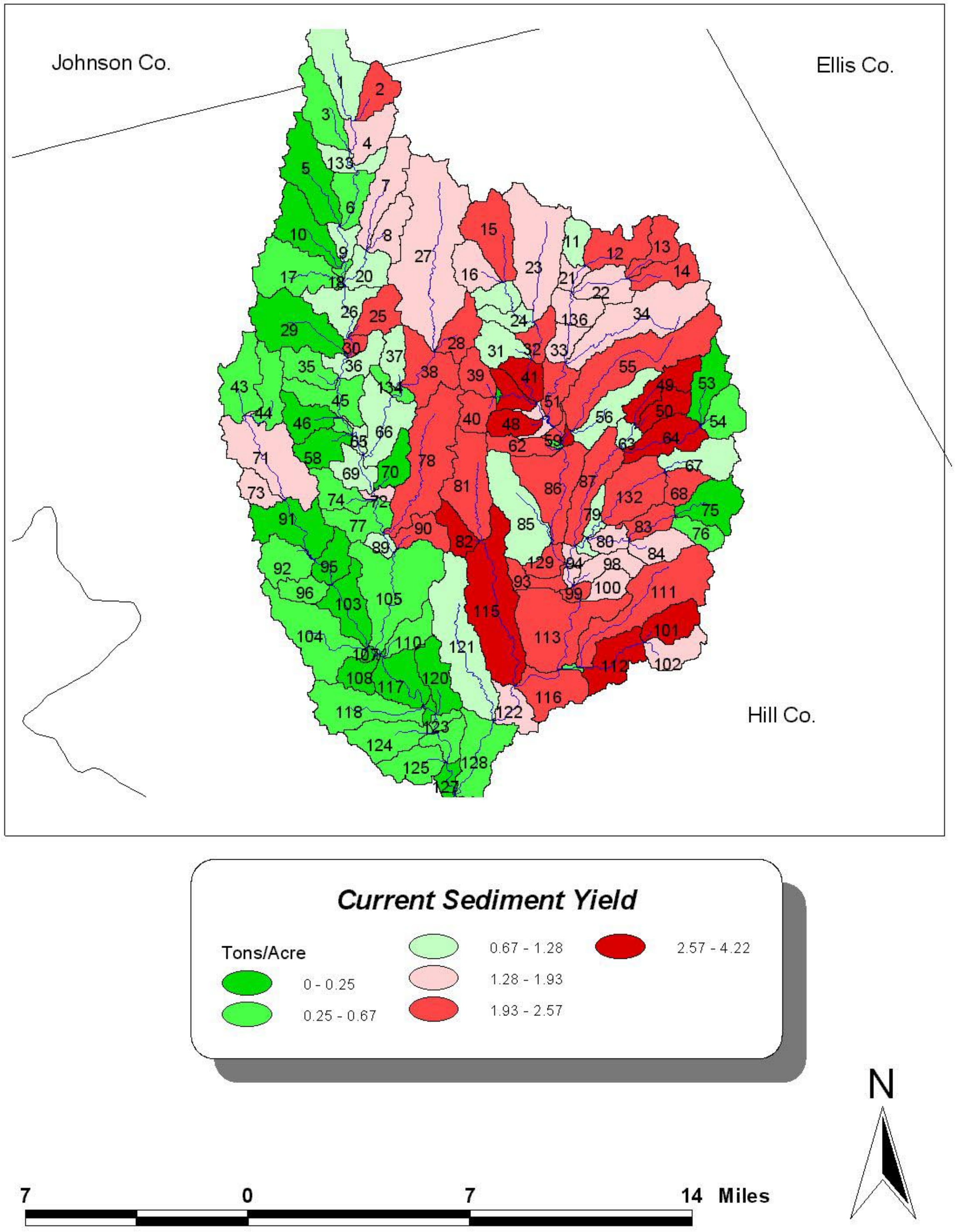

Figure 13. Predicted average annual sediment yield by subbasin for current condition, Aquilla watershed, 1950 through 2000.

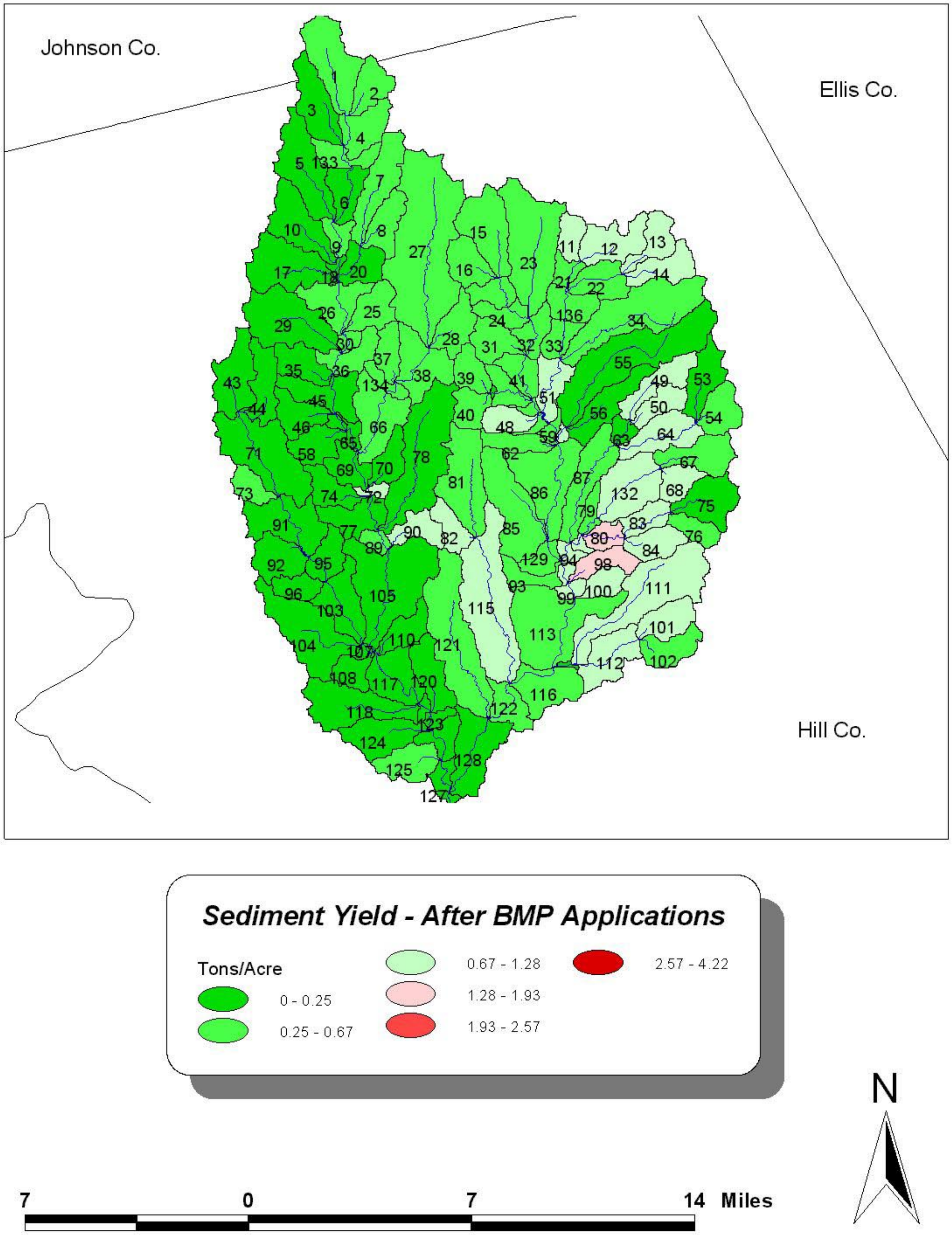

Figure 14. Predicted average annual sediment yield by subbasin after BMP application, Aquilla watershed, 1950 through 2000.

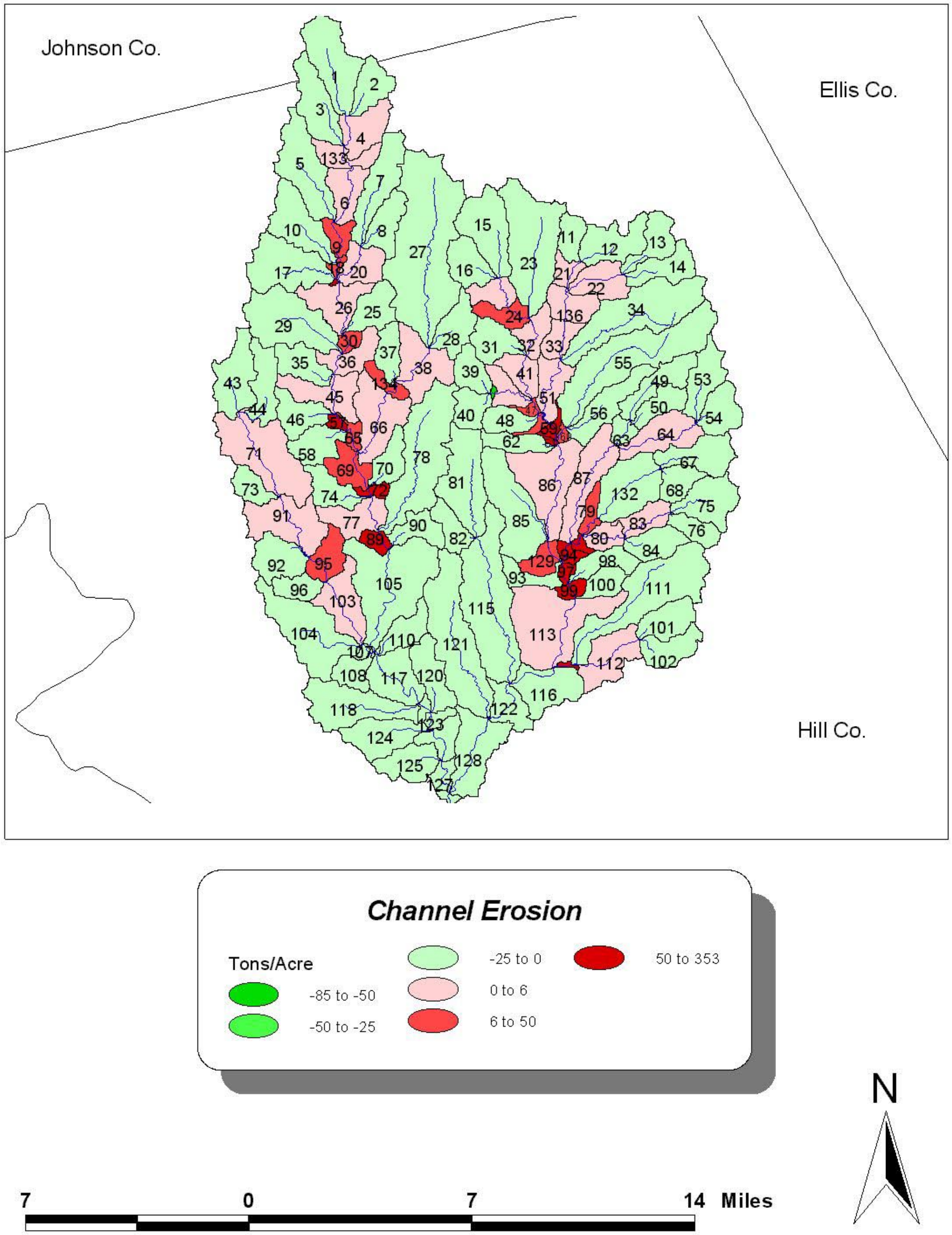

Figure 15. Predicted average annual sediment from stream channel erosion (per unit subbasin area) for current condition, Aquilla watershed, 1950 through 2000.

Flow Validation and Short Term Sediment Simulation

Sediment accumulations in Lake Aquilla from October 1995 to present day are unknown. It was determined that a short term simulation would provide some insight to sediment deposits between 1995 (TWDB sediment survey) and December 2000. In addition, the National Weather Service began collecting climate data at three additional stations in or near the Aquilla watershed in 1992 **(Table 2)**. Addition of these stations to SWAT input may reduce spatial inconsistencies, and provided an opportunity to validate previous flow predictions.

The period 1996 through 2000 was simulated assuming current watershed conditions and using climate data from all six climate stations. No adjustments were made to calibrated model inputs. Measured stream flow for this period was not available. However, records of changes in lake levels were obtained from BRA and used to estimate inflow to Lake Aquilla for comparison with simulated flow. Time series plots of monthly observed and simulated flow are shown in **Figures 16 and 17**. Monthly simulated flow compared favorably with observed, although the simulated was higher. This was probably due to inaccuracies in converting reservoir storage data to inflow, climate variability, or because evaporation and seepage in Lake Aquilla were not considered in the SWAT simulation.

Predicted sediment volume to the lake for the 1996 – 2000 period was 2,834,606 metric tons. Assuming sediment density was 55 pounds per cubic foot, the volume of sediment deposition for this period was 2,608 acre-feet.

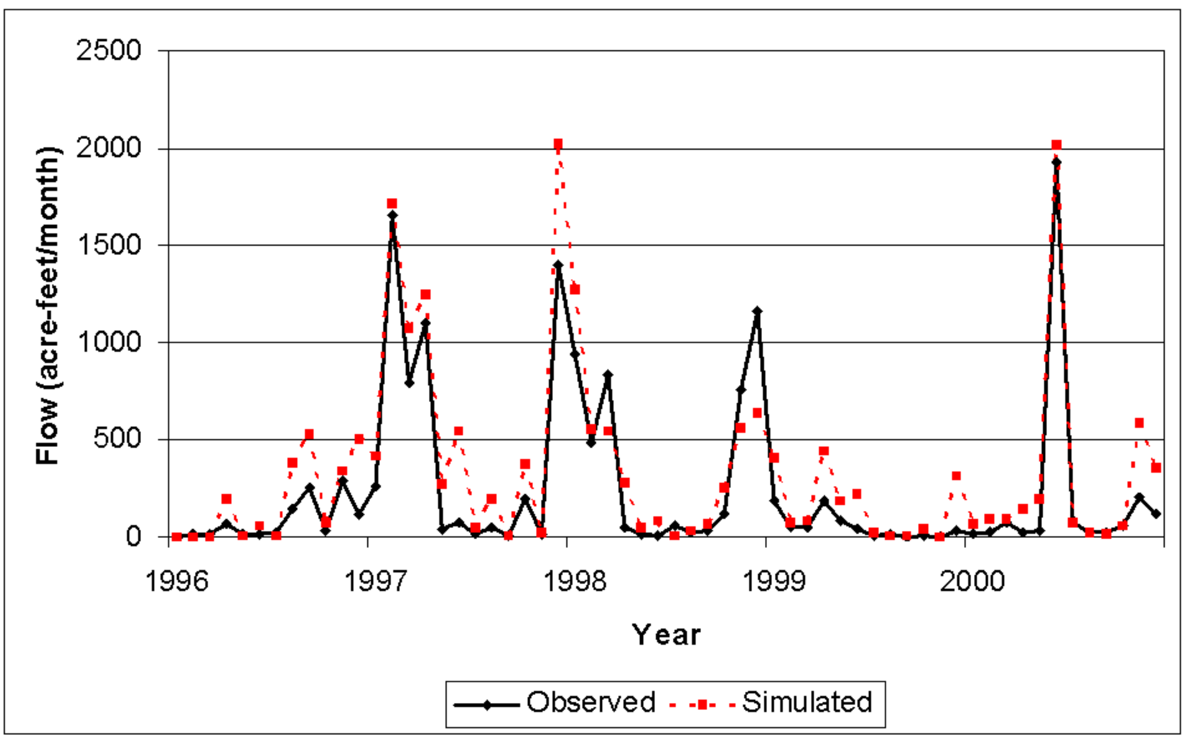

Figure 16. Monthly observed and simulated inflow to Lake Aquilla, 1996 through 2000.

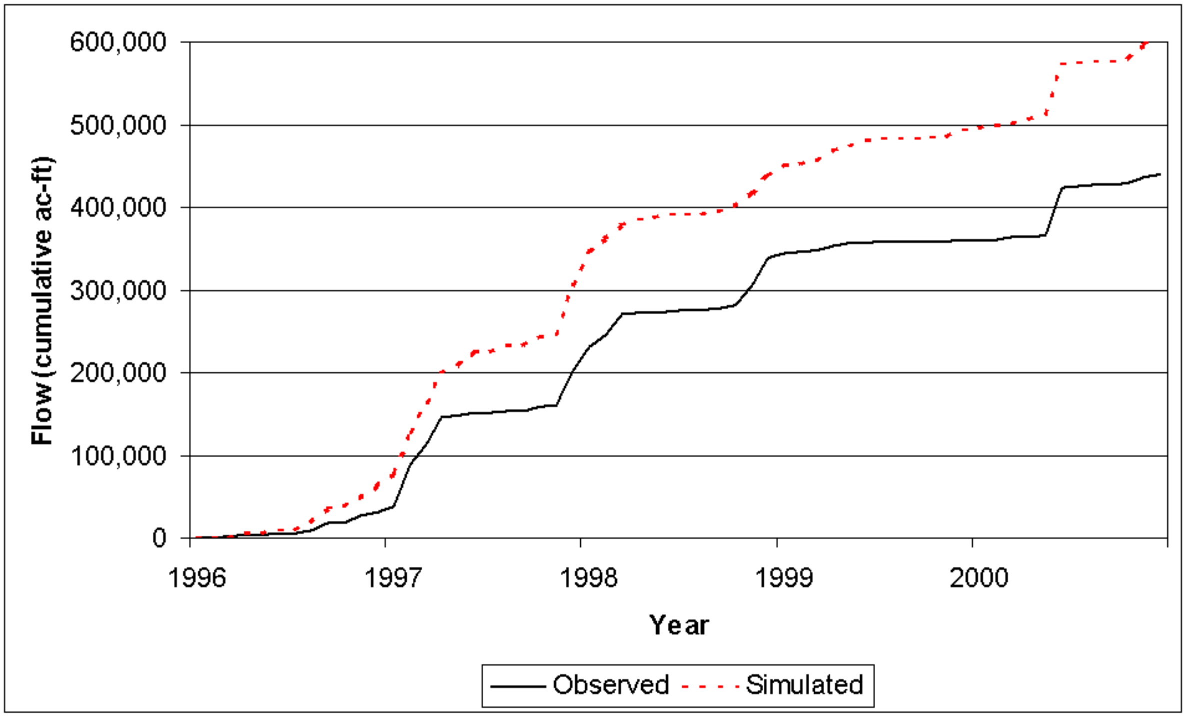

Figure 17. Cumulative monthly observed and simulated inflow to Lake Aquilla, 1996 through 2000.

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PART I

APPENDIX

NOTES FOR TABLES 10 AND 11 (PART I – APPENDIX)

In Table 10, the fraction of "Cropland" in each subbasin is based on actual input to SWAT and will not agree exactly with cropland percentages in Table 8. We set the landuse filter in SWAT at 5 percent, which means that any landuse comprising less than 5 percent of a subbasin was ignored in the model input. In addition, SWAT re-allocates areas to the other landuses when a landuse of less than 5 percent is ignored and dropped out of the model. The result is usually a small adjustment in area for each category of landuse in SWAT input.

Also in Table 10, the "SEDIMENT YIELD" is the sediment resulting from erosion in the land phase portion of the model only. This sediment yield is affected by BMP's and ponds. Dams or structures modeled as "reservoirs" have no effect on this sediment yield, but instead affect the sediment loadings from erosion in the water phase of the model.

In Table 11, the sediment into and out of the reach includes all sediment from erosion in both the land phase and water phase of the model. However, the difference between "SEDIMENT INTO REACH" and "SEDIMENT OUT OF REACH" is the sediment load resulting from stream channel erosion only (water phase of model). Subbasins with no upstream subbasins draining into them have zero "SEDIMENT LOAD", since water phase erosion is not considered. Subbasins with zero or negative "SEDIMENT LOAD", and that have upstream subbasins draining into them, have deposition occurring in the channel. Subbasins containing reservoirs (131 & 132) have negative "SEDIMENT LOAD", indicating deposition in the reservoir. For subbasins with positive "SEDIMENT LOAD", stream channel erosion is occurring in those subbasins. Small subbasins with large upstream drainage areas flowing through them usually show the largest "SEDIMENT LOAD" per unit subbasin area.